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SPIDER (ARACHNIDA: ARANEAE) DIVERSITY, SEASONALITY AND STATUS IN CASHEW AGRO-ECOSYSTEM

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ABSTRACT

An exhaustive study was conducted to record the spider diversity in cashew plantations of Directorate of Cashew Research, Puttur, Karnataka, India. Regular surveys for occurrence of spiders and collections were done from November 2009 to March 2012. A total of 104 species of spiders belonging to thirteen families *viz*., Araneidae, Clubionidae, Corinnidae, Gnaphosidae, Nephilidae, Oxyopidae, Pholcidae, Pisauridae, Salticidae, Sparassidae, Tetragnathidae, Theridiiae, and Thomisidae were recorded. Out of these, 30 species were classified as very common, 17 species common, 31 species rare and 26 species very rare. The families, Salticidae and Araneidae contributed 33.65 and 22.12 per cent of the spider fauna respectively in cashew ecosystem. Different diversity indices of spider population were calculated. Guild structure analysis of the collected spiders revealed 6 feeding guilds *viz*., orb-web builders, foliage hunters, ground hunters, space builders, stalkers and ambushers. The study of seasonal variation revealed that 36 species were present during winter which increased to 85 during monsoon and 28 were present during summer and 10 species were recorded all- round the year. This is the first report of the spider fauna from cashew ecosystem, in India.
Key words: Cashew, spiders, diversity, seasonality, biological control

INTRODUCTION

Cashew, *Anacardium occidentale* Linn. is an important plantation crop of India, which was introduced by Portuguese during the 16th century. The potential of this crop in the international trade was first realized by India in the early 1900s through the export of cashew kernels. Now, India has the largest area under cashew and stands as the second largest producer of cashew in the world.

Insect pests such as, Tea Mosquito Bug (TMB) and Cashew Stem and Root Borer (CSRB) are the major pests of cashew, leading to significant economic losses. Even though usage of pesticides is optimized for pest management in cashew. In Integrated pest management (IPM), a system – oriented approach is needed. Hence, a clear understanding of not only the target insect- pests, but also associated natural enemies and their interaction is a pre-requisite before formulating an effective

management module. In cashew agro-ecosystem, spiders are the most abundant generalist predators of arthropod- pest complex. Natural conservation or employing these natural enemies to manage the insect-pests is one the important component in IPM strategy. A better understanding of spider guilds, their composition, and factors influencing spider community structure is essential for future studies on the arthropod fauna of agro-ecosystems (Riechert and Lockley, 1984).

The global list of spider fauna is approximately 42,055 belonging to 3821 genera and 110 families (Platnick, 2011). Currently 39,882 valid described species of spiders in 3676 genera and 108 families have been described (Platnick, 2007). The spider fauna of India is represented by 1520 spider species belonging to 377 genera and 60 families (Sebastian and Peter, 2009). However, Coddington and Levi (1991) estimated that up to 170,000 species could exist. There still exist major gaps in our knowledge of biodiversity of spiders in many areas within varied ecosystems of India.

Spiders are potential biological control agents in agro-ecosystems (Riechert and Bishop, 1990). Many researchers have provided descriptions of spider species abundance or composition in a variety of agro-ecosystems (Wisnieswka and Prokopy, 1997). Other researchers provided quantitative observations on the abundance of spiders (Carroll and Hoyt, 1984) or recorded spider predation events (Riechert and Bishop, 1990). Spiders, despite their ubiquity and high densities, have not received the recognition they need in order to be fully utilized in this enterprise, although their treatment in several recent compendia is encouraging (Toft and Riedel, 1995). Many field evaluations conducted over several years have demonstrated that spiders can reduce insect population and crop damage they cause. The knowledge on diversity and distribution of spiders in India is sparse as compared to other regions of the world. The most comprehensive description on Indian spiders are by Tikader (1987); Sebastian and Peter (2009).

In cashew, Basu Choudury (1962) had documented that a large number of spiders belonging to seven families occur predominately in Kerala. A list of arthropod predatory fauna recorded from cashew panicles was given by Sundararaju (2003) comprising five spider species along with an unidentified spider and eight ant species. Species – spectrum and inter-relationship between ant and spider fauna studies conducted by Pathummal Beevi and Mahapatro (2008) depicted 35 species of spiders in cashew agro- system. They classified spiders in to four spider-guild classes namely stalkers, orb weavers, foliage and ground runners; web – making pattern of spiders were discussed, their predatory potential in laboratory were studied.

However, in India, the study on diversity of spiders in plantation crops like cashew is meager. Most of these studies were limited to the identification of spiders and investigation of the dominant spider species. There has been no study on their seasonal variation and their ecological impact. The present study attempts to improve the understanding of resident spider population their status and seasonal variations in their diversity in the cashew agro-ecosystem. This is the first report of the spider fauna from cashew ecosystem, in India.

MATERIALS AND METHODS

Study area

The present study was carried out in cashew plantations of Directorate of Cashew Research, Puttur and Experimental Station, Shanthigodu, consisting of 148 ha (12.45°N latitude, 75.4°E longitude) in the Karnataka state of Southern India. The altitude is 90 m above Mean Sea level. The temperature in the area ranges from 16.0°C to 38.0°C. The region receives an annual rainfall of 429.6 mm to 1827.9 mm during the southwest monsoon between June and September. The relative humidity varies from 43% to 97%.

Methodology

Field observations were made for three years from November 2009 to March 2012. Specimens were collected following direct observation/hand picking method from cashew trees. Wide- mouthed long glass tubes were used for spider collection. Collections were made only from foliage and tree-trunk of cashew trees excluding tree- basins and soil considering their predatory potential on cashew pests. The collected spiders were preserved in 70 % alcohol solution in glass vials labeled with date of collection. The collected spider specimens were grouped into four categories *i.e.* very common (spiders found in > 35 collections), common (10-35 collections), rare (5-10 collections) and very rare (< 5 collections). The spiders were categorised regarding their abundance in cashew and not with respect to their seasonal occurrence.

Identification of Spiders

The adult spiders were identified to family level using available literature (Tikader 1987, Sebastian and Peter 2009). Species level identification of the Voucher specimens (labeled with date of collection) were done by taxonomists of Division of Arachnology, Sacred Heart College, Cochin, Kerala, India. The monthly data on abundance of spiders in cashew plantations were prepared for each season through date of collection and recording of frequent occurrence of identified spiders.

Data Analysis

The diversity of spiders were analyzed by widely used indices viz., the Shannon-Wiener index, which is sensitive to changes in the abundance of rare species in a community, and the Simpson index, which is sensitive to changes in the most abundant species in a community (Solow, 1993).

Diversity indexes:

a) Shannon-Wiener index is defined as:

$$H = -\sum p_i \ln (p_i)$$

H = the Shannon-Wiener Diversity Index

p_i = the relative abundance of each group of organisms

b) Simpson index is defined as:

$$D = \frac{\sum n_i (n_i - 1)}{N (N-1)}$$

D = the Simpson index

n_i = the number of species of family i

N= total no. of species

The Evenness index is measure of how evenly species are distributed in sample. When all species in a sample are equally abundant an Evenness index will be at its maximum decreasing towards zero as the relative abundance of the species diverges away from evenness.

Evenness index:
E = In (*N1*)/In (*N0*).
Where: *N1* = number of abundant species in the sample, and *N0* = number of all species in the sample.

Feeding guild were classified as stalkers, web builders, space builders, ambushers, ground runners and foliage runners as per Uetz *et al.* (1999).

RESULTS

A complete checklist of spider species is given in Table 1. A total of 104 species spread over 56 genera and 11 families were identified.

Salticidae was the numerically prominent family, forming 33.65 % of the sample. It was followed by Araneidae (22.12), Theridiiae (8.65), Thomisidae (7.69), Oxyopididae (5.77) and Tetragnathidae (5.77), Gnaphosidae (3.85) and Nephilidae (3.85) and then Sparassidae (2.88). All other families contributed less than 2% to the overall abundance (Fig. 1). The most abundant genus recorded is *Myrmarachne.* The families with highest number of total species are the jumping spiders (Salticidae) with 35 species, followed by orb web weavers (Araneidae) with 23 species. The comb-footed spiders (Theridiiae) and crab spiders (Thomisidae) are next (9 and 8 species each) followed by lynx spiders (Oxyopididae) and long – jawed orb weavers (Tetragnathidae) with 6 species each. The mouse spiders (Gnaphosidae) and long-legged orb weavers are next with 4 species each followed by giant crab spiders (Sparrasidae) with 3 species and all other families have 2 or less than 2 species (Table 2).

Table 1. Spider diversity with its seasonality and status in cashew

Sr. No.	Scientific name	Common name	Season	General abundance
1	*Arachnura* sp.	Scorpion-tailed spider	M	VR
2	*Araneus bilunifer* Pocock*	Orb-weaver	S,M	VR
3	*Araneus bituberculatus* Simon	Orb-weaver	M	VC
4	*Araneus mitificus* Simon	Kidney garden	M	R
5	*Araneus nympha* Simon	—	M	VR
6	*Argiope pulchella* Thorell	Garden cross spider	W,S,M	VC
7	*Argiope* sp.	Garden cross spider	S,M	R
8	*Cyclosa fissicauda* Simon	—	M	R
9	*Cyrtarachne keralaensis* Thorell*	Grass jewel spider	S,M	VR
10	*Cyrtarachne raniceps* Pocock**	Grass jewel spider	S,M	VC
11	*Cyrtarachne* sp.	Grass jewel spider	M	R
12	*Cyrtarachne* sp.	Grass jewel spider	S	R
13	*Cyrtophora citricola* Forsskal	Jungle tent web spider	W,M	R
14	*Cyrtophora* sp.	Garden tent web spider	M	R
15	*Cyrtophora unicolor* Doleschall	Garden tent web spider	W,M	R
16	*Eriovixia laglazei* Simon	Grey bird dropping spider	M	C
17	*Gasteracantha geminate* Fabricius**	Garden spiny spider	M,W	VC
18	*Neoscona mukerjeri* Tikader*	Common garden spider	W,S	VC
19	*Neoscona poonaensis* Tikader	—	W	VC
20	Neoscona pavida Simon	—	W,M	R
21	*Neoscona* sp.		S	R
22	*Parawixia dehanii* Doleschall	Abandoned web spider	M	C
23	*Thelecantha brevispina* Doleschall	False gasteracantha	W	VR
	Clubionidae			
24	*Clubiona* sp.	Patchy sac spider	W	VR
25	*Matidia* sp.		W	VR
	Corinnidae			
26	*Castianeira zetes* Simon**	Black–ant mimicking spider	M	VR
	Gnaphosidae	—		
27	*Drassodes* sp.		M	VR
28	*Poecilochroa barmani* Tikader*		M	R
29	*Poecilochroa* sp.		M	R
30	*Scotophaeus* sp.		S	R

	Nephilidae			
31	*Nephila* sp.	---	M	C
32	*Nephila pilipes* Simon	Giant wood spider	M,W	VC
33	*Herennia multipuncta* Doleschall	Ornamental tree trunk spider	M,W	VR
34	*Herennia* sp.	Ornamental tree trunk spider	M	VR
	Oxyopidae			
35	*Oxyopes birmanicus* Thorell*	Crossed lynx spider	S	C
36	*Oxyopes shweta* Tikader	White lynx spider	W,M	VC
37	*Oxyopes* sp.		W	VC
38	*Oxyopes* sp.		M,W	VC
39	*Oxyopes sunandae* Tikader*	Orange lynx spider	W,S,M	VC
40	*Peucetia viridana* Stoliczka	Green lynx spider	S	R
	Pholcidae			
41	*Pholcus* sp.	Long- bodied cellar spider	M	VR
42	*Uthinia atrigularis* Simon	Leaf-dwelling pholcid	M,W	R
	Pisauridae			
43	*Pisaura gitae* Tikader*	Common nursery web spider	M	R
	Salticidae			
44	*Asemonea tenuipes* O. P Cambridge	Tailed jumper	M,S	VC
45	*Bavia kairali* sp.nov	Scorpion jumper	W,M	R
46	*Brettus albolimbatus* Simon	Crescented jumper	M	R
47	*Brettus* sp.	—-	M	R
48	*Carrhotus* sp.	—-	M	C
49	*Carrhotus viduus* CL Koch	Black and white jumper	M	C
50	*Epeus* sp.	—-	W,S,M	VC
51	*Epeus indicus* Proszynski*	White spotted green jumper	W,S,M	VC
52	*Epeus tender* Simon	Orange crested jumper	M	VR
53	*Epocilla aurantiaca* Simon	Jolly epocilla	S,M	R
54	*Hasarious adansoni* Audouin	Adanson's house jumper	S	VC
55	*Hasarious* sp.	—-	S	VC
56	*Hyllus semicupreus* Simon**	Heavy–bodied jumper	W,S,M	VC
57	*Menemerus* sp.	Common wall jumper	M	C
58	*Myrmarachne orientalis* O. P Cambridge**	Brown ant-mimic	M	C
59	*Myrmarachne plataleoides* Tikader	Red ant-mimic	S,M	VC
60	*Myrmarachne ramunni* Narayan*	—-	M	R
61	*Myrmarachne* sp.		M	R
62	*Myrmarachne* sp.		M	R
63	*Myrmarachne* sp.		M	C
64	*Myrmarachne* sp.		M	C
65	*Myrmarachne* sp.		M	R
66	*Myrmarachne* sp.		M	VR
67	*Myrmarachne* sp.		M,W	C

68	*Myrmarachne* sp.		M	R
69	*Myrmarachne* sp.		M,W	VR
70	*Myrmarachne* sp.		M	VR
71	*Phintella vittata* C. L. Koch	Banded phintella	W,S,M	VC
72	*Plexippus paykulli* Audouin	Small zebra jumper	W,S,M	VC
73	*Plexippus petersi* Karsch	Small zebra jumper	W,S,M	VC
74	*Plexippus sp.*		S,M	VC
75	*Rhene rubigera* Thorell	——	M	C
76	*Siler semiglaucus* Simon	Metallic jumper	M	VR
77	*Telamonia dimidiate* Simon	Two–stripped jumper	W,S,M	VC
78	*Thiania bhamoensis* Thorell	Metallic blue jumper	M	R
	Sparassidae			
79	*Heteropoda sp.*	Common house spider	W,S,M	VC
80	*Olios* sp.	Green crab spider	M	C
81	*Olios* sp.		M	VC
	Tetragnathidae			
82	*Leucauge decoratA* Blackwall	Three-humped spider	W	R
83	*Leucauge sp.*		M	VR
84	*Leucauge pondae* Tikader*	Pond leucauge spider	M	VR
85	*Opadometa fastigata* Simon	Humped silver spider	W,M	VR
86	*Tetragnatha fletcheri* Gravely*	—-	M	C
87	*Tetragnatha viridorufa* Gravely*	Green tetragnathid spider	M	VC
	Theridiiae			
88	*Achaearancea tepidariorum* C.L. Koch	Wall corner spider	W,M	VC
89	*Achaearanea mundula* L Koch	Rolled leaf spider	M	VR
90	*Argyrodes ambalikae* Tikader*	—-	W,M	VR
91	*Argyrodes gazedes* Tikader*	Parasitic comb-footed spider	W,M	VR
92	*Ariamnes flagellum* Doleschall	Whip spider	M	VR
93	*Chrysso argyrodiformis* Yaginuma	Brush- legged spider	M	C
94	*Chrysso nigra* OP Cambridge	Black pearl spider	M	R
95	*Chrysso* sp.		M	R
96	*Theridion* sp.		M,W	VC
	Thomisidae			
97	*Camariacus formosus* Thorell	Brown flower spider	S,M	C
98	*Camariacus* sp.		S,M	C
99	*Loxobates sp.*			R
100	*Oxytate virens* Thorell	Green crab spider	S,M	VC
101	*Strigoplus netravati* Tikader*	Grass crab spider.	W	R
102	*Thomisus lobosus* Tikader*	White crab spider.	W,S,M	VC
103	*Thomisus pugilis* Stoliczka*	Common rose spider	W	VR
104	*Xysticus* sp.	Brown crab spider	M	VR

.....continued

VC-Very Common, C-Common, R-Rare, VR-Very rare.
W-winter (November, December, January, February) S-summer (March, April, May), M-monsoon (June, July, August, September, October).
*Indicates endemic to India, **Indicates endemic to South Asia
– Common name not available

Table 2. Distribution of genera and species of different families in cashew ecosystem

Sr.No.	Family	Guild	Genera	Species	Relative abundance	Status			
						VC	C	R	VR
1	Araneidae	Orb weavers	11	23	0.22	6	2	10	5
2	Clubionidae	Foliage runners	2	2	0.02	0	0	0	2
3	Corinnidae	Ground runners	1	1	0.01	0	0	0	1
4	Gnaphosidae	Ground runners	3	4	0.04	0	0	3	1
5	Nephilidae	Orb weavers	2	4	0.04	1	1	0	2
6	Oxyopidae	Stalkers	2	6	0.06	4	1	1	0
7	Pholcidae	Space builders	2	2	0.02	0	0	1	1
8	Pisauridae	Ambushers	1	1	0.01	0	0	1	0
9	Salticidae	Stalkers	16	35	0.34	12	8	10	5
10	Sparassidae	Foliage runners	2	3	0.03	2	1	0	0
11	Tetragnathidae	Orb weavers	3	6	0.06	1	1	1	3
12	Theridiiae	Space builders	5	9	0.09	2	1	2	4
13	Thomisidae	Ambushers	6	8	0.08	2	2	2	2
	Shannon-Wiener index (H)		2.03						
	Simpson index (1-D)		0.82						
	Evenness index (E)		0.83						

VC-Very common (spiders found in > 35 collections), C-Common (15-35collections), R-Rare(5-10 collections), VR- Very Rare (< 5 collections).

Table 3. Seasonal variation in number of spider species in cashew

Season	No. of spider species
Winter (November, December, January, February)	36
Summer (March, April, May),	28
Monsoon (June, July, August, September, October).	85
Throughout the year	10

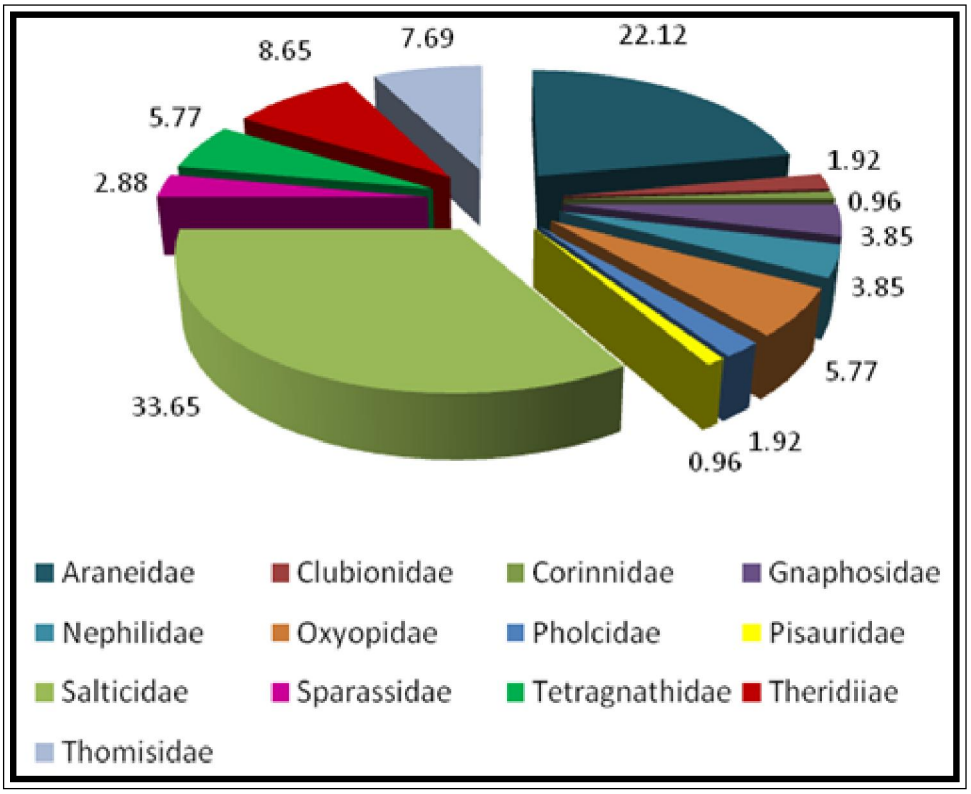

Figure 1. Percentage of spider families distributed in cashew

Figure 2. *Oxyopes swetha* predating on tea mosquito bug

The spiders sampled belong to six functional groups (guilds) based on their foraging behaviour in the field. The dominant guild was of the stalkers with 35 species. The orb web builders comprised of 33 species of spiders. Spiders of the families Araneidae, Tetragnathidae and Nephilidae fall under this category. Spiders of the category space builders formed the next dominant guild in this ecosystem comprising of 11 species of spiders. Ambushers (9 species) ground runners (5 species), and foliage runners (5 species) are the other functional groups (Table 2).

The diversity and evenness indices were calculated for the collected spiders. The Shannon index value was 2.03 while Simpson index value was 0.82. The Evenness index had a value of 0.83.

Most of the spiders from Araneidae are inhabitants of cashew canopy. In *Eriovixia, Neoscona* and *Rhene,* abdominal variations are noted with respect to colour patterns. The genus *Argiope,* commonly known as "Signature spider" is mostly found in orb web built in branches and sometimes webs are built on shrubs like *Lantana camera* which occur as weed in cashew orchards. Spiders belonging to the families, Tetragnathidae, Pisauridae inhabit mainly on ventral side of cashew leaves. Spiders from Nephilidae are found to construct large webs on trees with intermingling branches with neighbouring plants. The criss- cross branches, dead wood and branches touching the ground provides shelter for Theridiiae family members.

Salticids the most abundant spiders of cashew agro-ecosystem, dispersed in plant parts *viz*., shoots, leaves, flowers, panicles or fruits. The change in the colouration and ornamentation were also seen in the salticidae family members. *Myrmarachne* (ant- mimicking spiders) form bulk of salticid population in cashew. These spiders can be seen on the foliage in search of prey. The predatory potential of salticid spiders were observed to be higher than other spider groups. It was noticed (through direct observation) that the prey preference of spiders *viz*; *Telamonia dimidiate, Oxyopes shweta* (Fig.2) and *Oxyopes sunandae* were higher for TMB adults and nymphs in the cashew fields even though they feed on a wide range of insects.

Spiders exhibited seasonal variation in their occurrence in cashew orchards and the details are presented in Table 3.

DISCUSSION

Since the study was mainly based on visual searches and shaking of branches, other sampling methods such as pitfall trapping, fogging, sweeping would certainly reveal occurrence of few more species of spiders. Past studies in the world have shown that different methods tend to complement one another (Coddington *et al*., 1991; Russell-Smith, 1999). Earlier 35 species of spiders were

recorded in cashew agro-ecosystem (Pathummal Beevi and Mahapatro, 2008). However, during the present spider survey, it is found that the 104 species spiders exist in cashew under 56 diverse genera. Season wise, maximum number of genera is recorded from June to October (Monsoon) indicating their life cycle coinciding with that of prey population. Hsieh and Dyck (1975) mentioned the reduction of green leafhoppers population in paddy fields during the predation by spiders. Numerous surveys of spiders and their arthropod prey have been conducted in managed crop ecosystems, showing that spiders constitute a significant proportion of the predator guild (Young and Edwards, 1990).

A diversity index incorporates both species richness and evenness in a single value (Magurran 1988). Two diversity indices used here are Shannon-Wiener index (), which is sensitive to changes in the abundance of rare species in a community, and Simpson index (D) which is sensitive to changes in the most abundant species in a community. In the present study, value (2.03) indicates the presence of rare species in the spider community. If values for diversity indices are often difficult to interpret, species evenness are often presented as separate values. In this form they provide important insights into the ecological changes that occur over time or the differences between ecological communities (Bisby 1995). When all species in a sample are equally abundant an evenness index will be at its maximum, decreasing towards zero as the relative abundance of the species diverges away from evenness. Probably, the most common evenness index used by ecologists is 'E'. An evenness index should be independent of the number of species in the sample. It has shown that the addition of a rare species to a sample that contains only a few species greatly change the value of 'E'.

Present research has paid more attention to incorporate the requirements of the vast fauna of spiders, into cashew management strategies. Perusal of literature on chemical con-trol of mirids reveals that endosulfan was the most effective. In the recent past, however the allegedly ecocidal episode involving endosul-fan use in cashew production in the Kasargod and Kannur Districts of Kerala, has initiated an unabated debate on these issues, the related environmental-impact assessment, the 3 R's (Resistance, Residues, and Resurgence), and es-pecially the human health hazards. In the quest to replace heavy reliance on insecticides with an ecologically-based pest management strategy. This rich diversity of spiders is also indicative of the overall biodiversity of cashew plantations since spiders are considered to be useful indicators of the species richness and health of terrestrial ecosystems (Noss 1990) and amply emphasizes the need for preserving cashew patch intact from a biodiversity conservation perspective. An increase in the spider population depends on prey availability and, if the density of prey becomes higher, spiders are expected to increase proportionally to some extent. The peak population density of spiders coincides with an increase of insect pests (Kiritani *et al*. 1972).

With an inventory of three years, 104 spider species could be recorded, which is comparatively high. This indicates that the spider diversity in cashew needs further long term detailed studies using additional methodologies. As spiders are the major group of natural enemies, the present work will form the baseline for the new approaches of Integrated Pest Management strategies of cashew.

CONCLUSION

The present study depicted the vast, diverse fauna of spiders associated with the plantation crop; cashew. The study can form the base line for exploring the predatory fauna of cashew for IPM strategies of tea mosquito bugs. The cashew ecosystem has a diverse spider community and further research is indicated to evolve a better understanding of their ecology. These studies should include exploring other factors which are important in influencing spider diversity and richness in this agro-ecosystem, viz. effects of insecticides, availability of prey species, intra- and interspecific competition, surrounding habitats and climatic factors.

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